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Development and Characterization of a Bidirectional Optical Multipass Cavity for Counter-propagating High Energy Pulsed Laser Applications

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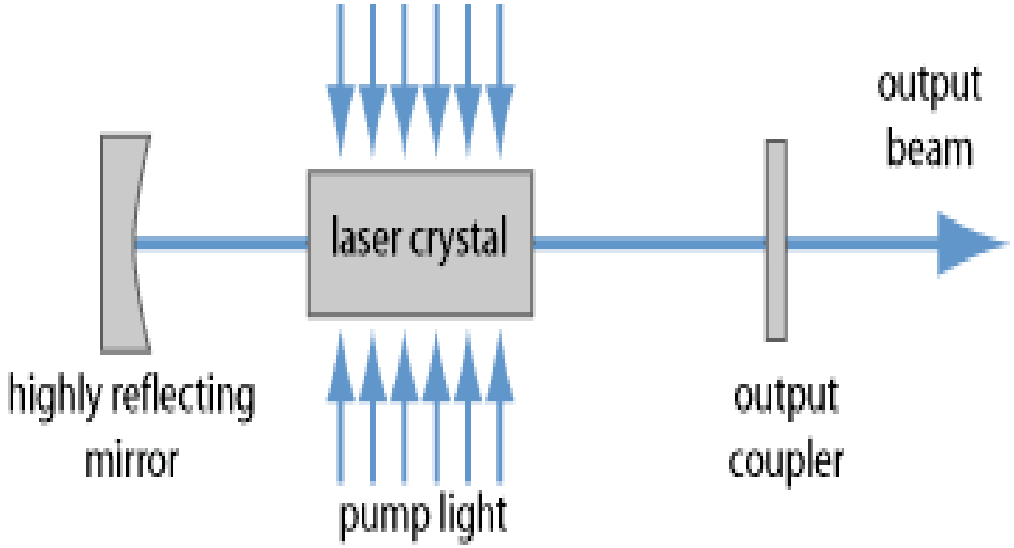
Overview

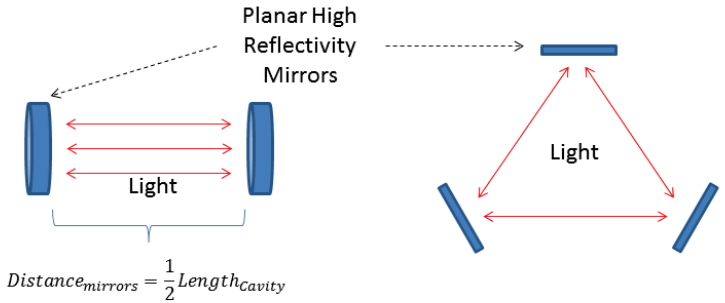
- **Multipass cavity was developed for counter-propagating high energy pulsed laser applications**
- **Cavity was designed to potentially allow for repeated temporal and spatial superposition of counter-propagating pulses**
  - Trap: One-time change in pulse polarization state
  - Maintain: Optical focusing system employed
  - Optimized: by simulation
  - Experimentally characterized

Optical Cavities

- **Cavities**
  - provide a closed path for circulation of light
  - Function follows form:
  1.) Active & resonant
  2.) Passive & resonant /nonresonant

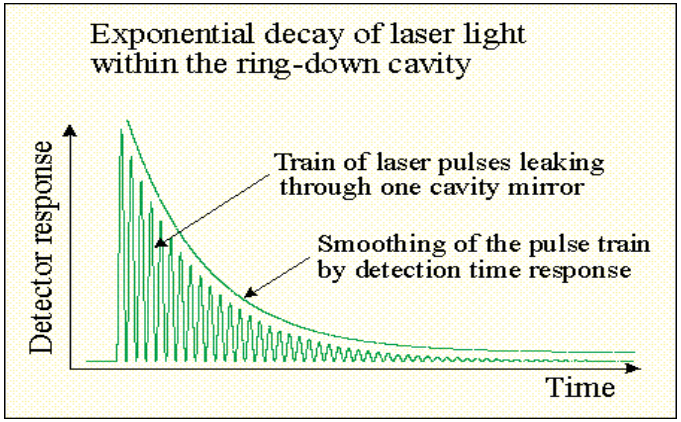


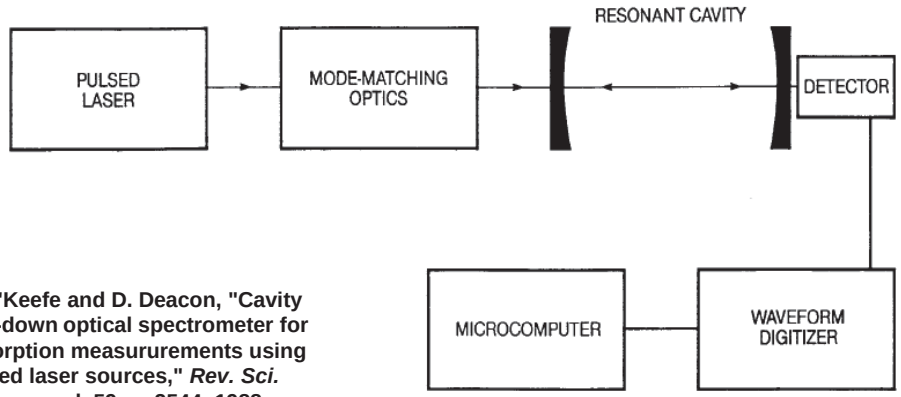
- **What can they do for me?**
  - Increased laser pulse repetition rates
  - Increased laser-gas energy deposition efficiency
  - Increased absorption path length
  - Increased sensitivity in spectroscopy studies
  - Variety of energy storage & amplification schemes



Prior Multipass Cavity Applications

1. Potential non-resonant laser gas heating
2. X- and γ-ray production using Inverse Compton scattering
3. Chemical Kinetics using Infrared Multiple Photon Dissociation (IRMD)
4. Raman scattering for molecular structure studies
5. Cavity ring-down laser absorption spectroscopy (CRDS)
6. Laser absorption spectroscopy





A. O'Keefe and D. Deacon, "Cavity ring-down optical spectrometer for absorption measurements using pulsed laser sources," *Rev. Sci. Instrum.*, vol. 59, p. 2544, 1988.

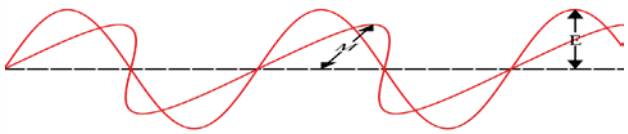
Experimental Cavity Requirements

Experimental

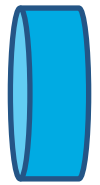
- **For the requirement of this study, any potential cavity design must:**
  - Efficiently trap/contain pulsed laser light at 532 nm
  - Simultaneous injection pulses
  - Exhibit high damage thresholds
  - Spatial/temporal superposition
  - Reduce beam diameters down to ~50 μm

Implementation

- **Problem: Time reversibility**
- **Possible solutions**
  1. Laser Resonant Cavity
  2. Long path length
  3. Modification and Trap
     a. Color Change Cavity
     b. One-time Polarization Change
- **Selected Approach: Pockels Cell**
  - Linear electro optic Pockels effect
  - Introduces net relative phase shift between orthogonal components
  - Can act as a dynamic λ/2 or λ/4 wave plate/dynamic phase retarder/frequency shifter



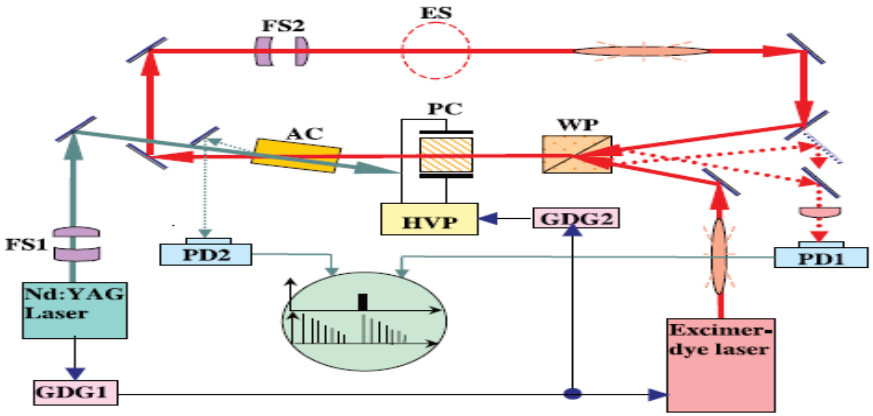
$$T_o = T_1$$



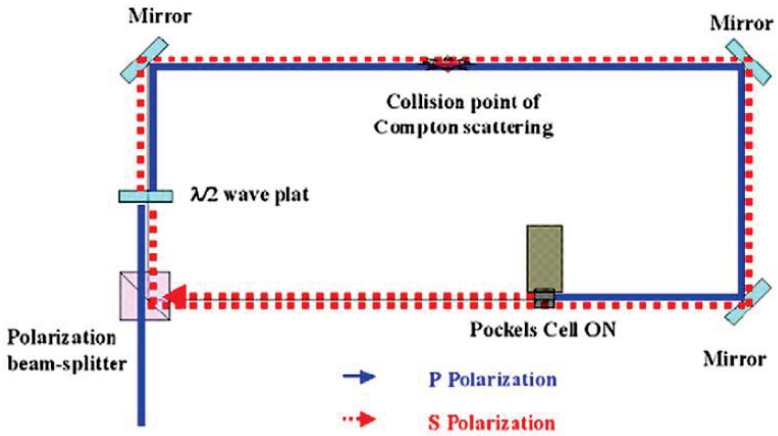
0° Mirror

Single Pockels Cell Cavity Design

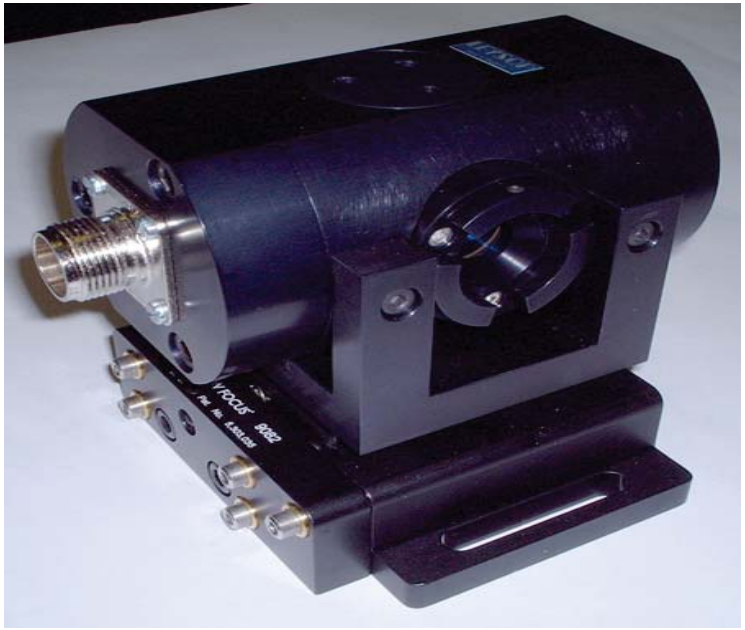
Mohamed et al.



Meng et al.



Pockels Cell



- Pockels effect is a linear electrooptic effect
- Birefringence

  Index of refraction

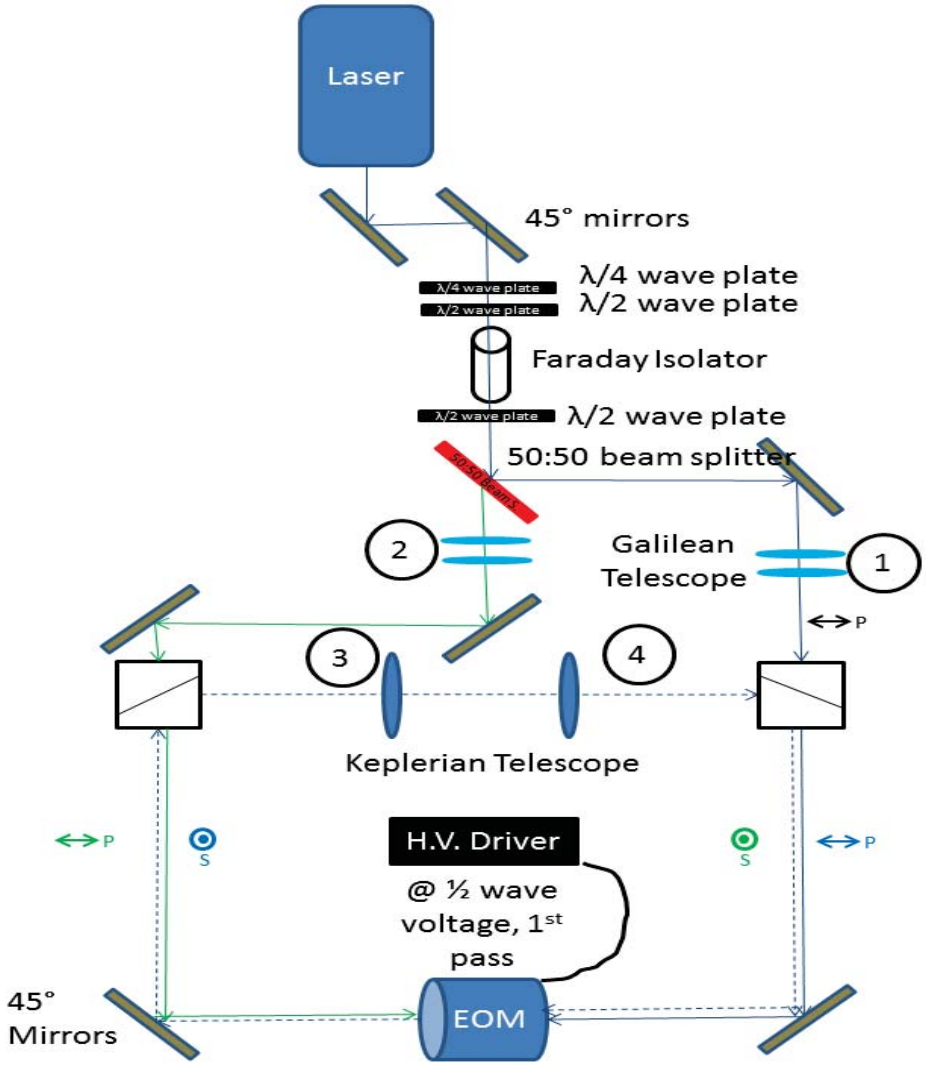
$$n = \frac{c}{v}$$

- Pockels cell used for dynamic phase retardation
- 2 important voltages

$$V_{\lambda/2} = \frac{\lambda}{2n_o^3 r_{63}}$$

$V_{\lambda/2}$ for KD*P at 532 nm ≈ 3.6 kV

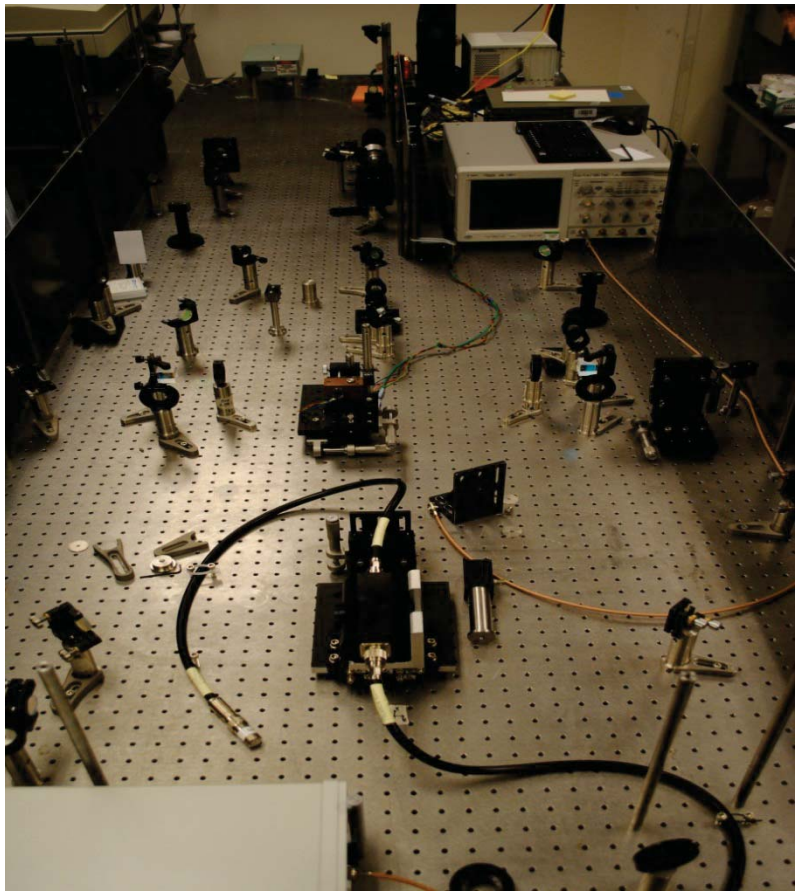
Single Pockels Cell Cavity Design



- Conditioning wave plates
- Faraday Isolator
  - **Faraday effect**
  - **Faraday rotator & 2 Glan polarizers**
  - **Non-reciprocal rotation**
  - **One-way valve**
- Galilean Telescopes
- PBCs
  - **p/s polarization**
  - **Differential response**
- Pockels Cell/Driver
  - **@ $V_{\lambda/2}$ on 1st pass**
  - **V=0 on subsequent passes**
  - **One-way valve**
- Keplerian

Implementation

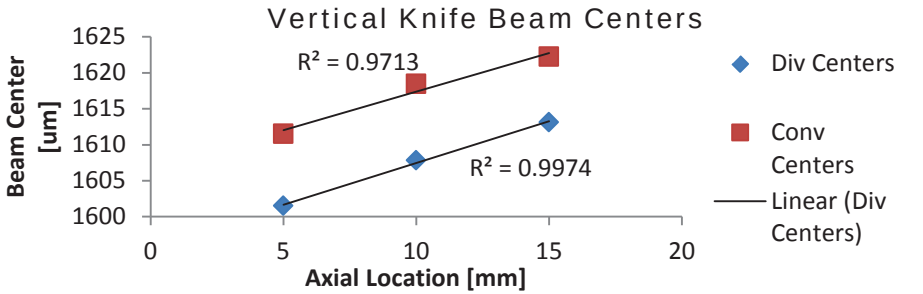
Experimental Setup

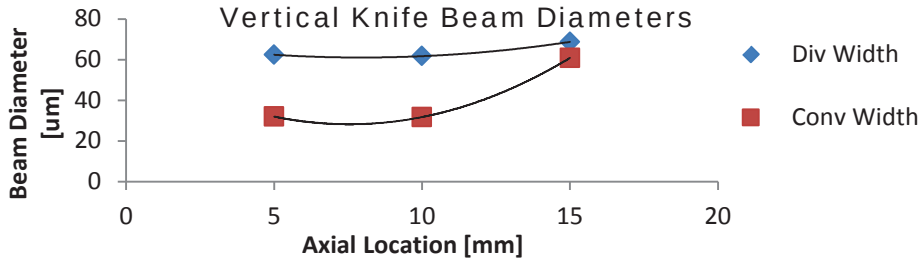


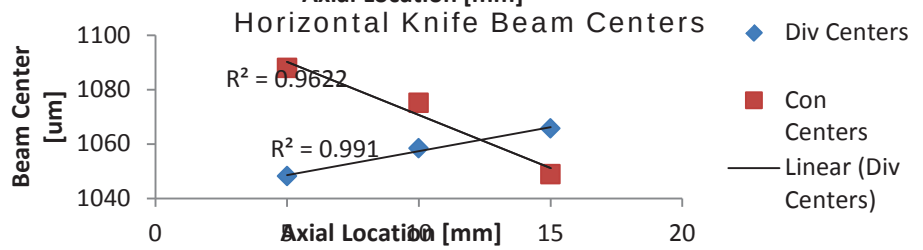
Equipment

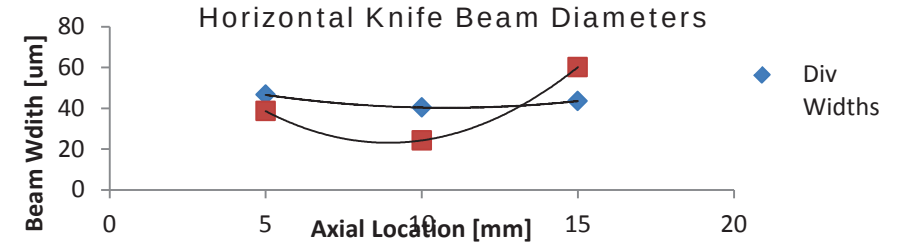
- **Laser(s)**
  - Nd:YAG 532 nm, 5 ns FWHM, Continuum Minilite/Powerlite
- **Cavity length 2.4284 m (96 in); rt pulse time 8.09 ns**
- **Timing Control**
  - SRS DG535 x3
- **Pockels cell/driver**
  - Leysop Ltd. UPC 6 mm aperture; 250 ps rise, 6 ns width; KD*P 650MW/cm2
- **Intra- and extra-cavity focusing system**
- **Knife Edge System**

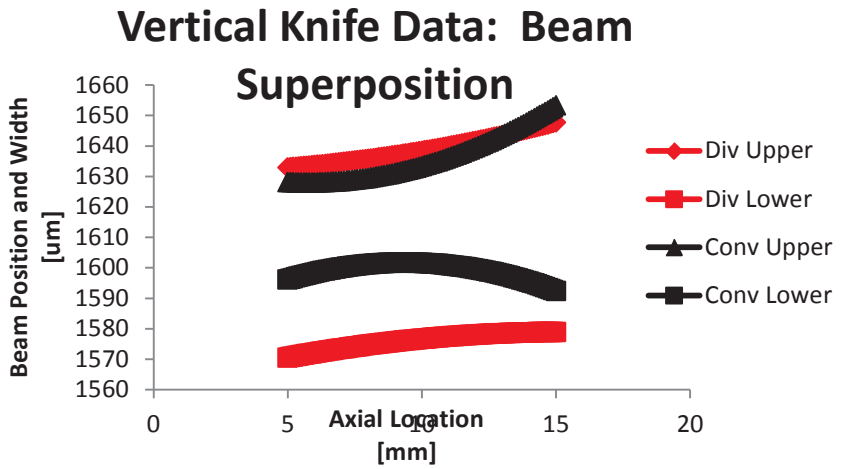
Results: Spatial Superposition

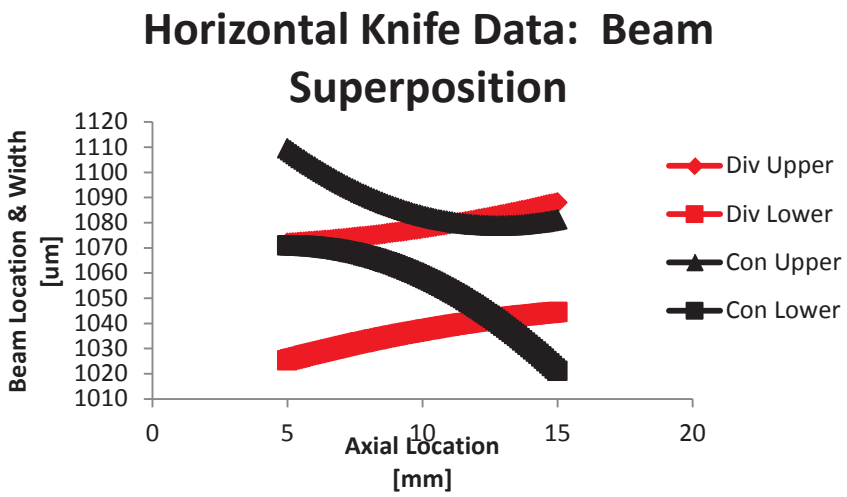




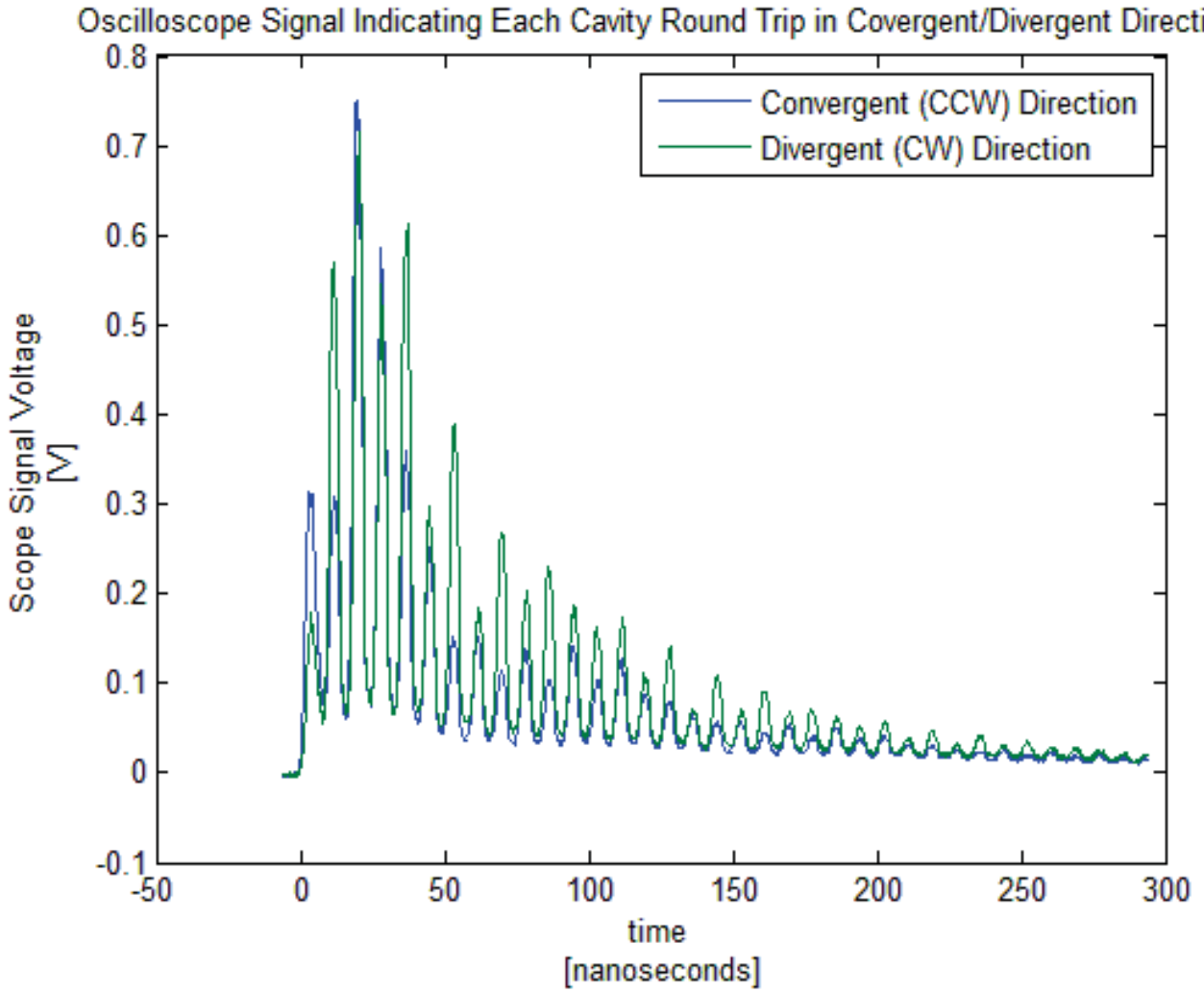






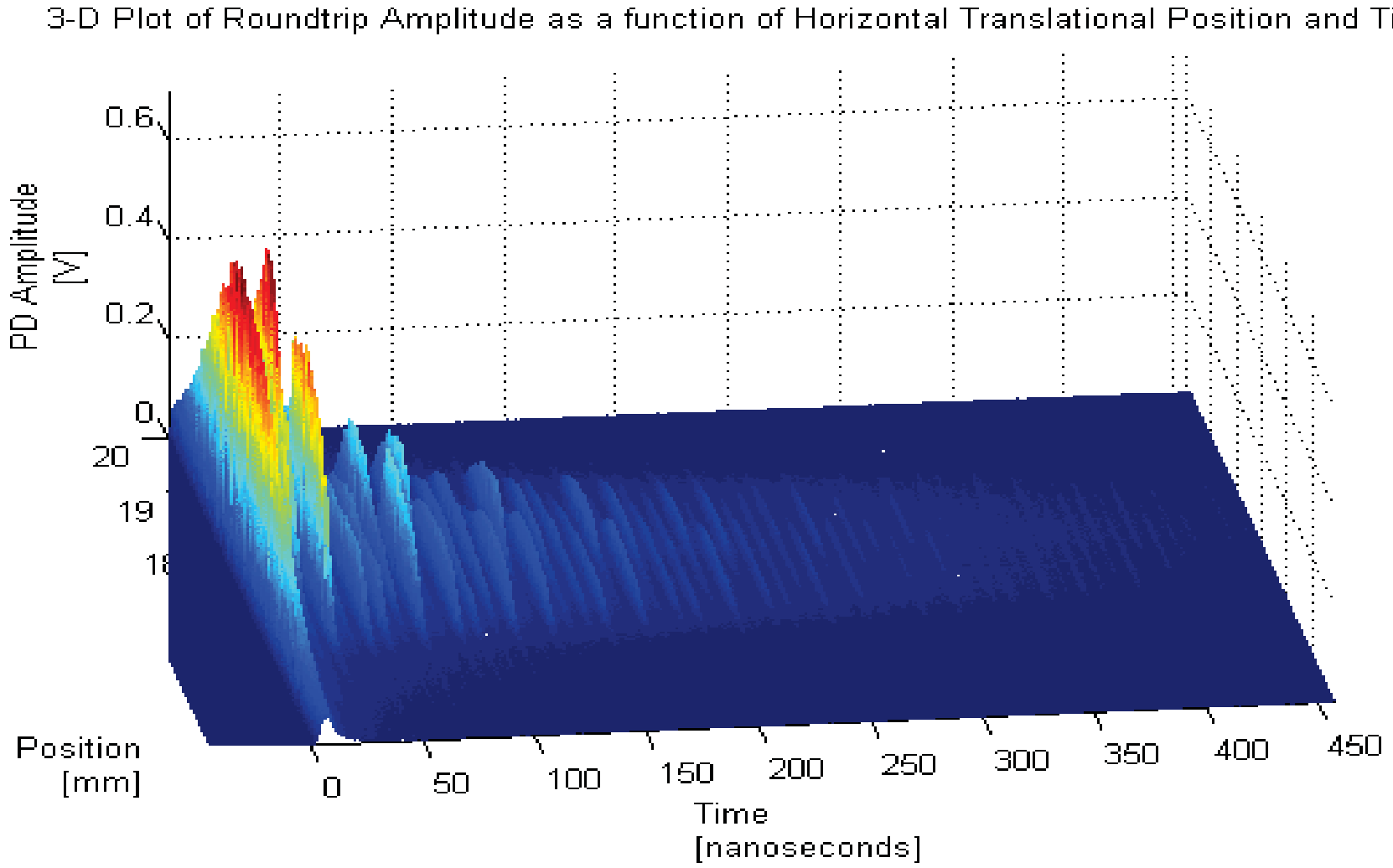


Results: Temporal Superposition



- **Temporal pulse superposition**
- Greater than 40 rt
  - 532 nm, 5 ns FWHM, Continuum Minilite, 4 mJ
- Cavity length 2.4284 m (96 in); period 8.09 ns
- Pockels cell/driver
  - Leysop Ltd. UPC 6 mm aperture; 250 ps rise, 6 ns width
- Periodicity matches cavity
- PD
  - Active area .006 mm^2

Results (continued)



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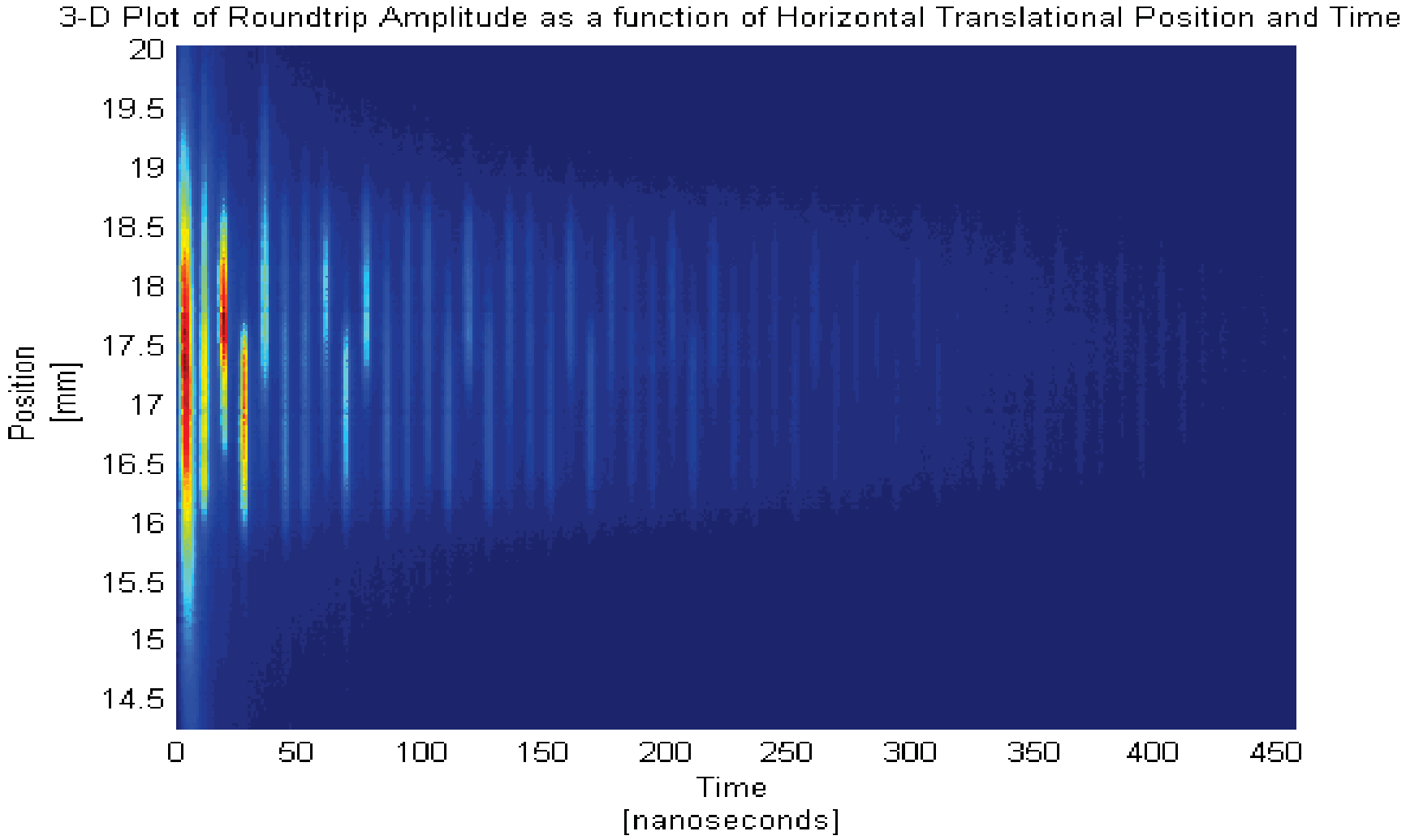

Summary

- **First bidirectional cavity for counter-propagating high energy laser pulses**
  - Temporal superposition confirmed within cavity on every round trip
  - Spatial superposition confirmed on 1st R.T.
  - 40+ R.T. observed for 4 mJ initial pulse energy
  - Cavity indicates a dual-stability condition
  - 8.3 fold increase in energy deposition ‘opportunity’ over the single pulse/single pass case